2008

Earthworms and E. coli: A Perilous Combination for Drainflow Water Quality

Garey Fox
Oklahoma State University, garey.fox@okstate.edu

Rameshwar S. Kanwar
Iowa State University, rskanwar@iastate.edu

Robert W. Malone
United States Department of Agriculture

Earthworms and *E. coli*

A perilous combination for drain flow water quality

Garey A. Fox, Ramesh Kanwar, and Rob Malone

Researchers at Oklahoma State University (OSU), Iowa State University (ISU), and the USDA-ARS National Soil Tilth Laboratory (NSTL) have formed a unique research team to solve an important water quality problem. This team is addressing the transport of pathogens (specifically, the indicator organism *Escherichia coli or E. coli)* through soils and, more specifically, the role of macropores in the transport of *E. coli* to subsurface drains. Pathogen contamination of water supplies is now considered one of the top water-quality issues in the United States and around the world.

A macropore directly connects to a sub-surface drain. A polymer resin was poured from the surface, and then the soil was excavated around the macropore. *(Photo courtesy of Martin Shipitalo, USDA-ARS, Coshocton, Ohio, USA)*

Macropores and subsurface drains

Field studies on subsurface drain plots commonly exhibit spikes in contaminant concentrations when rainfall events occur shortly after manure, fertilizer, or pesticide applications. It is hypothesized that this occurrence is due to macropores that are directly connected to subsurface drains. A direct connection to subsurface drains means a direct connection to water in ditches and rivers/streams and, hence, contamination of those water bodies.

Some of these macropores are present due to extensive earthworm burrow networks. In fact, USDA-ARS researchers at Coshocton, Ohio, led by Martin Shipitalo, have documented the detailed interaction of earthworm macropores and subsurface drain lines. Earthworms come to the soil surface to feed, breed, and migrate and then return to the soil in the vicinity of the subsurface drain because of its favorable moisture regime. Studies have shown that macropores located within 50 cm (20 in.) on either side of the drain line can potentially be directly connected between the surface and subsurface drain.

macro•pore (mak'ro por) *n.* a large (usually greater than 2 mm or 0.08 in.) continuous opening in the soil caused by soil cracking, plant roots, and biological activity that acts as a conduit for flow and contaminant transport

Intrigued by the data

The authors, ASABE members Garey Fox (Biosystems and Agricultural Engineering, OSU) and Rob Malone (NSTL) began working together with George Sabbagh at Bayer CropScience in Stillwell, Kan., investigating immediate breakthrough of pesticides through these directly connected macropores. In Illinois field sites, rainfall events shortly after pesticide application caused large spikes in pesticide concentrations in drain flow. Numerical models were unable to simulate these concentration spikes unless they were modified to include the presence of directly connected macropores.

With more and more field studies indicating large concentrations of *E. coli* in drain flow shortly after animal manure application, the researchers teamed with ASABE member Ramesh Kanwar (Chair, Agricultural and Biosystems Engineering, ISU), ASABE member Carl Pederson (Research Assistant, Agricultural and Biosystems Engineering, ISU) and microbiologist Tom

At right: Garey Fox *(right)* and Jorge Guzman inspect an earthworm macropore in soil from the ISU Nashua Research Experimental Station in northeast Iowa. *(Photo by Todd Johnson, OSU)*

Moorman (NSTL) to develop an integrated field, laboratory, and numerical modeling study recently funded by the USDA Cooperative State Research, Education, and Extension Service (CSREES) as part of their National Research Initiative (NRI) grant program (Award No. 2007-35102-18242).

Research now and ongoing

As part of the three-year (2007-2010) NRI project, innovative laboratory column studies are being performed at OSU to study *E. coli* transport with artificial macropores. It is believed that the primary transport of pathogenic microorganisms in most soils occurs through macropores that bypass the filtering and adsorptive effects of the soil matrix. The column studies include a subsurface drainage boundary condition with macropores of varying lengths that are either directly connected to the soil surface or buried underneath the soil surface. The buried macropores simulate tillage or other management practices that disrupt macropore networks at the surface. Water containing *E. coli* is applied at the soil surface, and then concentrations of *E. coli* exiting from the macropore and drain are monitored.

Innovative laboratory column studies investigating the transport of *E. coli* to subsurface drains with surface-connected and buried macropores. The picture on the left shows the soil column packed with soil and installed pencil-size tensiometers for measuring soil pore-water pressure. On the right is the soil column unpacked to demonstrate the macropore setup with the cutout showing the tube that samples the macropore flow exiting from the perforated pipe used to simulate a zero-pressure boundary condition (e.g., subsurface drain).

Directly connected macropore emits smoke during a trial smoke-test experiment at the ISU Nashua Research Experimental Station. *(Photo by Jorge Guzman, OSU)*

The research also includes field experiments at the ISU Nashua Research Experimental Station in northeast Iowa. The field experiments include smoke tests to identify directly connected macropores, whereby smoke is injected at the outlet of the tile drain. Concentrated smoke plumes on the soil surface then indicate a direct pathway between the subsurface drain and the soil surface. Initial smoke tests indicated approximately 3.2 macropores per m (one macropore per ft). Liquid swine manure, containing *E. coli*, is applied to the subsurface drained plot. *E. coli* transport studies are then conducted using a rainfall simulator with continual monitoring of drain flow for *E. coli*. Four field experiments will be performed over the next two years (spring and fall) on two plots at Nashua.

In the later part of the study, the research results from the field and laboratory experiments will be utilized in the modification of a lumped macroporosity, subsurface drainage model for predicting *E. coli* transport through directly connected macropores. Our initial results, however, are confirming the prominent role of directly connected macropores on transporting *E. coli* to subsurface drains.

The macropores studied in this research are also connecting more than just contaminants and subsurface drains. They are also connecting cultures. Funding by the USDA NRI program provided monies for Ph.D. students at both OSU and ISU. Jorge Guzman (Ph.D. student, OSU) is from Columbia and Hoang Kim Chi (Ph.D. student, ISU) is from Vietnam. These two students frequently communicate on procedures and results from the laboratory and field studies. Their OSU and ISU dissertations will be connected by macropores and earthworms!

ASABE member **Garey A. Fox,** assistant professor, Department of Biosystems and Agricultural Engineering, Oklahoma State University, Stillwater, USA, Garey.Fox@okstate.edu; ASABE member **Ramesh Kanwar,** professor and chair, Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, USA, rskanwar@ias,tate.edu; ASABE member **Rob Malone,** agricultural engineer with the USDA-ARS National Soil Tilth Laboratory, Ames, Iowa, USA, Rob.Malone@ars.usda.gov.